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Determining the Optimal Order Quantity Using a Simulation Model

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Abstract - The main objective of this paper is to develop a mathematical model to find the optimal order quantity for a particular product. We apply the simulation technique in order to achieve this objective. The order quantity directly depends on supply and demand which has to be determined under uncertainty. In this research paper we explain a scientific method to determine these uncertain factors with minimum risk. A regression analysis is performed to forecast the sales of the concerned product for the year 2007. The result of the regression analysis is used to build the mathematical model. This mathematical model is simulated using a simulation computer software package and obtained the optimal order quantity by using the results of the simulation.

Keywords. *Model, Optimal Simulation, Objective, Regression*

I. INTRODUCTION

Simulation models are logical descriptions of the interrelationships among elements of a decision problem or the sequence of events that occur in a system over time [4]. The major advantage of a simulation model is its ability to incorporate uncertainty in one or more input quantities. It captures probabilistic behavior and allows one to estimate probability distributions and key statistics such as mean, variance, etc. that cannot be derived analytically.

Naturally the fluctuation of the sales directly related to the market demand. Due to the effectiveness of the company's promotional activities, seasonal variations and competition with other suppliers, the quantity of sales in any given period cannot be determined with certainty. Therefore, the company has to make an order quantity of a certain product under certain uncertainty.

Understanding the probabilistic behavior of the sales of particular product, this paper uses a simulation model to determine the optimal order quantity for a wholesale supplier for a certain period of time by analyzing statistically the quantified risk involved in each demand quantity decision [1].

II. METHODOLOGY AND MATERIALS

We are analyzing the past sales data of the item, non-woven interlining using the method of linear regression analysis to find an approximate quarterly sales distribution for the year 2007. Furthermore, with the help of @Risk simulation computer software package we are analyzing the risk involved in each demand quantity to predict the optimal stock for each quarter in 2007 which satisfies the company requirements.

We use the monthly sales data of the non-woven interlining for the past 5 years. Since our objective is to find the optimal order quantities for each quarter of the year 2007, the quarterly sales in the past 5 years were calculated

using the collected data. Then, by categorizing these data according to the quarters, the respective quarterly sales for 2007 were obtained.

A. Regression analysis

The expected quarterly demands for each quarter in 2007 which is given in Table 1 were calculated with the use of the summary output obtained from the linear regression analysis method. The error in this quantity was proved to be normally distributed with mean (μ) = 0 and standard deviation (σ) = standard error which is obtained in the summary output given in Table 2. As shown in Table 3 the actual demand for each quarter in 2007 was taken to be the (expected demand) + (error), where error ~ $N(0,\sigma)$.

Table 1. *The expected quarterly demand*

Quarter	Expected Demand
Quarter 1	336,931 m
Quarter 2	296,937 m
Quarter 3	294,826 m
Quarter 4	459,949 m

Table 2. *Error for each quarterly demand*

Quarter		
Quarter 1	0	24,029 m
Quarter 2	0	15,612 m
Quarter 3	0	29,491 m
Quarter 4	0	15,196 m

Table 3. *The actual demand for 2007*

Quarter	Predicted Actual Demand(m)
Quarter 1	336,931 + Error
Quarter 2	296,937 + Error
Quarter 3	294,826 + Error
Quarter 4	459,949 + Error

B. Simulation model

With respect to the possible range for error, the actual demand will also fall into a range. Therefore, as shown in Table 4, Table 5, Table 6, Table 7 and Table 8 a simulation model was built using Excel spreadsheets expressing the company's sales and inventory schedule. Next, by varying the order quantities and by simulating the demand quantities which are given in Table 3, the respective profit distributions were found [2].

Mathematical model corresponding to the simulation model for the n^{th} quarter, n = 1, 2, 3, 4 :
Let
Unit cost = c, Unit price = p , Demand = D_n , Order quantity = x_n ,Revenue = R_n,
Cost = C_n , Profit = P_n , Budget = A , Amount of loan = L_n ,

Annual loan interest rate = r, Total interest of the loan for the n^{th} quarter = I_n and
Depreciation rate of the remaining quantity = d.

Following input and output variables are selected for the simulation model:
Input variables : D_n, c, p, x_n
Output variable : P_n

Objective : Maximize $P_n = R_n - C_n - (I_n + L_n)$
subject to the minimum risk, where

$$R_n = c \times \min(D_n, x_n),$$
$$C_n = c \times x_n,$$
$$L_n = C_n - A, \text{ and}$$
$$I_n = (L_n \times r) \times 0.25.$$

For the year 2007
Unit cost (c) = Current unit cost + Cost increment
Unit price (p) = Unit cost * (1 + expected profit percentage)

Current unit cost = Rs. 20 .
d = 2% , r = 18% .
Increment in cost ~Trian (0.30, 0.50, 0.80).
Expected profit percentage ~ Uniform (14.5% , 15.5%).

Table 4. *Cost data*

Unit Cost(c)	Rs.20.50
Unit Price(p)	Rs.23.57

Table 5. *Estimated parameters of the demand distribution for 2007*

Quarter		
First Quarter	336,926 m	24,050 m
Second Quarter	296,930 m	15,626 m
Third Quarter	294,827 m	29,435 m
Fourth Quarter	459,950 m	15,188 m

Table 6. *Possible Order Quantities* (x_n) (*in thousand meters*)

Quarter									
First Quarter	250	270	290	310	330	340	350	370	390
Second Quarter	230	250	270	290	300	310	330	350	370
Third quarter	190	210	230	250	270	290	300	310	330
Fourth quarter	400	420	440	450	460	480	500	470	480

Table 7. *Decision Variable* (x_n)

Quarter	Order Quantity (m)
First Quarter	250,000
Second Quarter	230,000
Third Quarter	190,000
Fourth Quarter	400,000

Loan Interest Rate (r) = 0.18

Depreciation Rate (d) = 2%

Cash Balance/Budget (A) = Rs. 1000,000

Table 8. *Output Result of the Simulation*

Quarter	Demand (m)	Revenue (Rs)	Cost (Rs)	Bank Loan (Rs)	Interest for the Loan(Rs)	Profit (Rs)
First Quarter	335,626	5,893,750	5,125,000	4,125,000	185,625	583,125
Second Quarter	296,776	5,422,250	4,715,000	3,715,000	167,175	540,075
Third Quarter	297,992	4,479,250	3,895,000	2,895,000	130,275	453,975
Fourth Quarter	458,860	9,430,000	8,200,000	7,200,000	324,000	906,000
					Net Profit	2,483,175

III. RESULTS AND DISCUSSION

After analyzing the summary statistics report, sensitivity analysis report [2] and the tornado charts for the profit distributions, the risk involved in each order quantity was quantified and the order quantities given in Table 9 were taken as the optimal order quantities which show a relatively high profit for each quarter in 2007:

Table 9. *The Order Quantities with the Maximum Profit Mean*

Quarter	Simulation No.	Order Quantity (m)	Minimum Profit (Rs)	Profit Mean (Rs)	Maximum Profit (Rs)
1	4	310,000	-568,242	674,806	755,428
2	3	270,000	-77,841	619,493	663,760
3	4	250,000	-541,476	560,140	613,019
4	3	440,000	161,871	975,908	1,053,350

Table 9 exhibits that even with the best values for mean profit there is some risk of obtaining negative profit. But these preferred outputs have a relatively fewer number of influential inputs compared to the other simulations for each quarter. Also, these order quantities give a relatively higher mean and a smaller standard deviation for the profit. Hence, to minimize the risk involved in profit, the values 310,000 m, 270,000 m, 250,000 m, and 440,000 m can be recommended as the optimal order quantities for the non-woven interlining in the 1st, 2nd, 3rd and 4th quarters for the year 2007, respectively. At the same time, it should be mentioned that these recommended figures may vary

with the variation of influential factors mentioned in the paper. However, it is understood that the simulation approach does not always guarantee the optimal output.

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